Mesoscale Convective Systems (MCSs) in Different Environments: GPM Observations

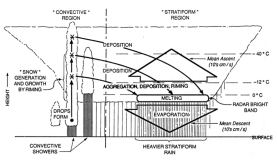
Xiaowen Li[1,2] Takamichi Iguchi[3,2] Chuntao Liu[4] Toshi Matsui[3,2] Wei-Kuo Tao[2]

1. GESTAR Program, Morgan State University; 2. NASA Goddard Space Flight Center; 3. ESSIC, University of Maryland, College Park; 4. Texas A&M, Corpus Christi

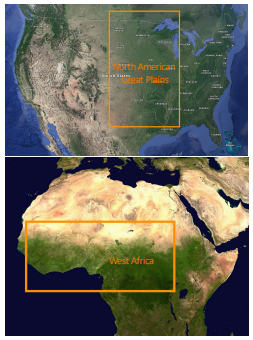
Motivation

We are interested in Mesoscale Convective Systems (MCSs) with extensive stratiform regions. These organized precipitation systems have relatively long lifespans, with quasi-steady mature stages that last more than several hours. The extensive, homogeneous stratiform region show consistent characteristics which can be reliably sampled by GPM satellite. Our goal is to find common statistics observed by GPM satellite, use them to understand cloud microphysical processes (e.g., aggregation of ice-phase particles), and to validate microphysical schemes in the Weather Research and Forecasting (WRF) model.

This study focuses on well-organized MCSs with widespread stratiform regions. For example, one type of highly organized form of MCS is a squall line, with a linear leading convective region, trailed by a wide stratiform region. These squall lines occur frequently during the summer months in North American Great Plains and West African, which are chosen to be our study areas. The squall line initiation mechanisms are similar at these two locations. The mountain ranges interact with mean flow and trigger convection downwind. These convection propagate with the mean flow and are often organized into MCSs by vertical wind shears. The GPM Precipitation Feature database with collocated level 2 data between May 1 and September 1, 2014~2017, are used in this study.

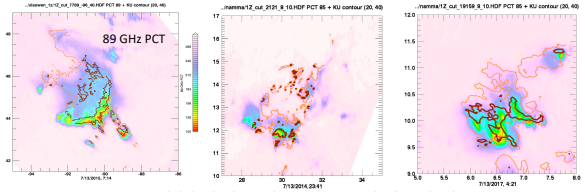


Schematic MCS cross section with a trailing stratiform region, copied from Houze (1989, QJRMS).



Classification of MCSs

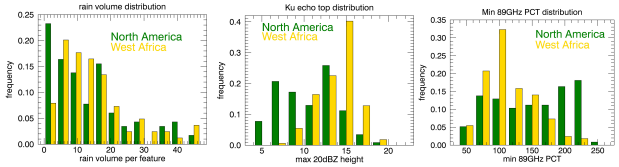
Squall Line	MCS General	MCS Other
Linear leading convective region with extensive trailing stratiform region; Along line length > cross line width in 89 GHz PCT.	Generally shows leading convective region and trailing stratiform region, but not well-defined; length < width	Has both convective and stratiform regions, but convection are embedded and scattered; include stratiform only; Number pixel > 1000
18 cases for North America	Number pixel > 1000	Not tallied for North America
74 cases for West Africa	99 cases for North America	92 cases for West Africa
	89 cases for West Africa	



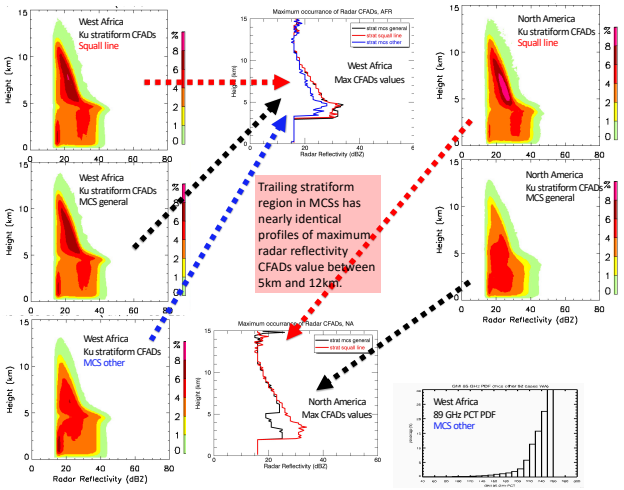
Images are GPM 89 GHz PCT, with dark red and orange lines representing Ku band 40 and 20 dBZ contours

MCS Statistics

Statistics of precipitation feature properties show more total volume rain per MCS, larger feature sizes, and much stronger convection in West African MCSs than in North American ones. The calculations exclude "MCS other" category.

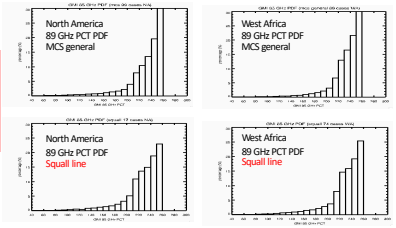


Vertical variations of radar CFADs show remarkable agreements between squall line cases and general MCS cases in the stratiform region.



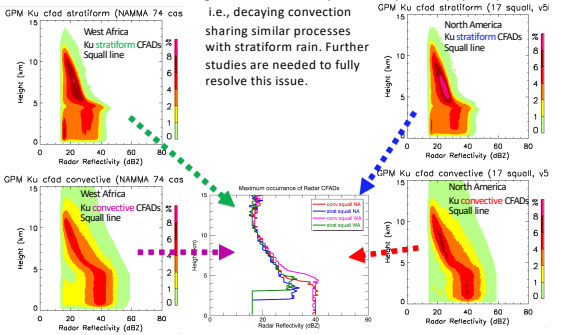
Trailing stratiform region in MCSs has nearly identical profiles of maximum radar reflectivity CFADs value between 5km and 12km.

89 GHz Polarization Corrected Brightness Temperature (PCT) also show consistant characteristics between the two different environments, as well as across different stratifications of MCSs.



Stratiform vs. Convective

When the Ku band radar reflectivity CFADs calculations are repeated in convective region, the same maxima profiles still exist. This may be because of some misclassifications of heavy stratiform rain into convective region. It could also be produced by similar physical processes, i.e., decaying convection sharing similar processes with stratiform rain. Further studies are needed to fully resolve this issue.



Conclusions and Ongoing Work

- Mesoscale Convective Systems (MCSs) with widespread stratiform region are identified at two different locations (North America Great Plains and West African), where they occur with high frequencies during summer months, using GPM observations between 2014 and 2017. It is found that vertical profiles of the maximum radar CFADs are nearly identical above melting layer, between the heights of 6km and 12km, in two different groups of MCSs: the highly organized squall lines and the less organized MCSs with trailing stratiform regions). This may be a manifestation of the homogeneous structure in the trailing stratiform region, where ice-phase particles fall through a weak updraft zone above melting level. The main particle growth mechanisms are through aggregation and deposition. Convective regions have much wider distributions in radar reflectivity. However, the maximum radar CFADs still have a very similar profile as the stratiform region. Further study are needed to understand the causes.

- Study of MCSs in two different environments confirms that, long-term TRMM/GPM observations (with single time frames for different cases) can provide meaningful constraints to cloud-resolving model simulations (with multiple time frames for a single case). With the robust vertical profile found this this study, GPM data can be used to validate and improve microphysical schemes with high confidence.

- In addition to GPM DPR data, distributions of GMI brightness temperature also show consistent characteristics across different MCS systems and in different environmental conditions. New variables observed by GPM, e.g., the differential reflectivity, 166 GHz brightness temperature and polarization, potentially can offer additional constraints and new insights in dynamical microphysical processes in MCSs.

- Using GPM data to validate cloud-resolving model requires satellite simulators to convert model output to GPM observables. Preliminary comparisons between WRF simulations of the May 20 MC3E case and the GPM observed statistics will be presented by Xiaowen Li on Thursday morning. Suggestions and comments will be highly appreciated.